School of Engineering

AIR FORCE INSTITUTE OF TECHNOLOGY

Air University

ANODIC POLARIZATION BEHAVIOR OF NICKEL 270 IN H_2-SATURATED, IN H_2SO_4

by

JAMES R. MYERS

Technical Report 67-6

Wright-Patterson Air Force Base, Ohio

Technical Report 67-6

1967

ANODIC POLARIZATION BEHAVIOR OF NICKEL 270 IN H_2-SATURATED, IN H_2SO_4

by

JAMES R. MYERS

Associate Professor

Department of Mechanics

Air Force Institute of Technology

Wright-Patterson Air Force Base, Ohio

ANODIC POLARIZATION BEHAVIOR OF NICKEL 270 IN H_2-SATURATED, 1N H_2SO_4*

Compiled By

J. R. Myers
Corrosion Research Laboratory
Air Force Institute of Technology
Wright-Patterson AFB, Ohio 45433

*Results of a round-robin test program conducted by National Association of Corrosion Engineers Technical Committee T-3L for Anodic Protection.

Background

At the March 1965 meeting of National Association of Corrosion Engineers (N.A.C.E.) Technical Committee T-3L for Anodic Protection a large number of attendees expressed an interest in participating in a round-robin potentiostatic anodic polarization test program. Since a large amount of data have been reported in the technical literature on the anodic behavior of nickel in sulfuric acid solutions, it was decided that the T-3L Program should consist of conducting a potentiostatic anodic polarization curve for pure nickel in hydrogen-saturated, 1N H_2SO_4 at 25°C using the experimental technique usually used in each participant's laboratory. Each participant was requested to submit a potentiostatic anodic polarization curve and supplemental data which were to include values for: (1) corrosion potential (E_{corr}), (2) cathode potential, (3) critical current density (i_{cr}), (4) critical potential (E_{cr}), (5) passive current density (i_p), and (6) Tafel slopes for anodic dissolution and transpassive behavior. All data were to be reported in accordance with the generalized potentiostatic anodic polarization curve (Figure 1) which was tentatively agreed upon at the March 1965 T-3L Committee Meeting.

Since it is well known that experimental procedure can strongly affect the potentiostatic anodic polarization curve, it was anticipated that widely different results would be reported. However, it was believed that the completion of such a round-robin test program would permit a more meaningful comparison of the data reported by various investigators and focus attention to the need for a standardized technique for conducting potentiostatic anodic polarization studies.

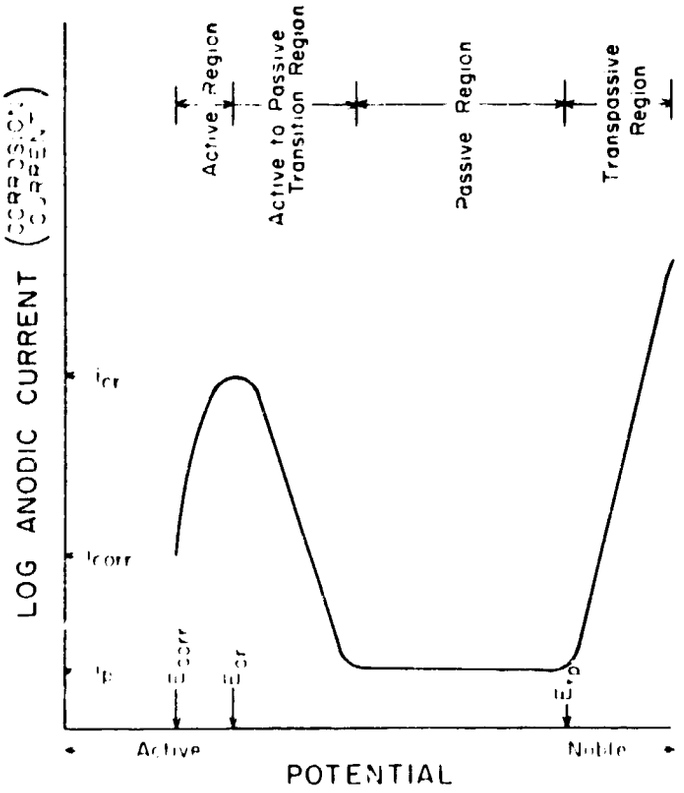


Figure 1 - Generalized Potentiostatic Anodic Polarization Curve Tentatively Agreed upon at March 1965 T-3L Meeting.

Subsequent to the 1965 T-3L Committee Meeting, specimens of pure nickel (Nickel 270) were provided the twenty-five investigators expressing a desire to actively participate in the round-robin test program. Of these twenty-five participants, fifteen (Table I) submitted results. These data were collected and compiled at the AFIT Corrosion Research Laboratory.

Table I

Participants in T-3L Round-Robin Test Program

Investigator	Affiliation
James R. Myers	Air Force Institute of Technology
Richard L. Martin	Monsanto Company
Olen L. Riggs	Continental Oil Company
Howard A. Porte	U. S. Naval Civil Engineering Laboratory
R. F. Steigerwald	E. I. du Pont de Nemours & Company
Howard Vaeth	Republic Steel Corporation
John D. Hatfield	TVA National Fertilizer Development Center
George Economy & G. A. DiBari	The International Nickel Company, Inc.
Edward L. Wiehe	Jones & Laughlin Steel Corporation
G. A. Saltzman	Crucible Steel Company of America
C. E. Locke	Continental Oil Company
Monte S. Walker	General Motors Technical Center
G. J. Biefer	Mines Branch of Canada
Ing. M. Prazak CSc.	State Institute for Material (Czechoslovakia)
James W. Johnson	University of Missouri at Rolla

Test Material

Because of the large number of investigators expressing an interest in participating in the T-3L test program, it was necessary to use Nickel 270 rod (furnished by The International Nickel Company) from two different heats. Since the test materials were produced using the same mill practice and had nearly the same chemistry (Table II), it was not expected that this possible variable would affect the anodic polarization curve. This was verified by tests conducted in the AFIT Corrosion Research Laboratory (see results reported by J. R. Myers in Appendix A).

Table II

Chemical Analysis of Nickel 270 Used in T-3L Round-Robin Test Program (values expressed in weight percent)

Heat	C	Mn	Fe	S	Si	Cu	Cr	Co
NP-327-H	0.002	<0.001	0.0006	0.001	0.0005	<0.001	0.0001	0.0004
NP-385-H	0.006	<0.001	0.0005	<0.001	0.0007	<0.001	0.0001	0.0003

Results

Anodic polarization data were submitted by the fifteen active participants of the T-3L Round-Robin Test Program. Of these fifteen: (1) eleven conducted their studies using a potentiostatic technique with H_2-saturated, 1N H_2SO_4; (2) two used a potentiostatic technique with N_2-saturated, 1N H_2SO_4; (3) one used a potentiostatic technique with air-saturated, 1N H_2SO_4; (4) one used a potentiostatic technique with 1N H_2SO_4 containing no saturating gas; and (5) one used a galvanostatic technique with H_2-saturated, 1N H_2SO_4. A compilation of the important polarization data reported by the fourteen participants using a potentiostatic technique is given in Tables IIIa and IIIb. (The data sheets and anodic polarization curves submitted by all fifteen investigators are included in Appendix A.) Examination of Tables IIIa and IIIb revealed that the reported polarization data are within the following limits:

Cathode Potential	-0.240 to -0.269 Volt vs. S.C.E.
Corrosion Potential (E_{corr})	-0.200 to -0.300 Volt vs. S.C.E.
Anodic Dissolution Tafel Slope	0.044 to 0.089 Volt/decade
Critical Current Density (i_{cr})	6.8 to 190 ma/cm^2
Critical Potential (E_{cr})	-0.100 to +0.400 Volt vs. S.C.E.
Passive Current Density (i_p)	0.0022 to 0.3 ma/cm^2
Early Transpassive Tafel Slope	0.040 to 0.185 Volt/decade
Oxygen Evolution Tafel Slope	0.08 to 0.485 Volt/decade

Conclusions

It has been established that experimental technique strongly affects the potentiostatic anodic polarization data for Nickel 270 in 1N H_2SO_4. However, as a result of this round-robin test program, it should be possible for the active participants to more meaningfully compare future data.

Recommendations

It is recommended that a statistical study be made (by an appointed committee) of the data contained in this report to quantitatively evaluate the affect of experimental technique on the potentiostatic anodic polarization curve.

Table IIIa

Comparison of Data Reported by Various Investigators for Potentiostatic Anodic Polarization Behavior of Nickel 270 in 1N H_2SO_4.

Investigator	Specimen Heat No.	Sat. Gas	Polarization Technique	Cathode Potential, Volt vs. S.C.E.	Corrosion Potential (E_{corr}), Volt vs. S.C.E.	Anodic Dissolution Tafel Slope, volt/decade	Critical Current Density (i_{cr}), ma/cm^2
Myers	NP-385-H	H_2	Stepwise	-0.269	-0.280	0.050 to 0.070	51
	NP-327-H	H_2	Stepwise	-0.266	-0.271	0.060 to 0.080	67
Martin	NP-385-H	H_2	Scan (- to +)	-0.267	-0.293	0.050	190
	NP-385-H	H_2	Scan (+ to -)	-0.267	-0.300	0.080	38.12
Riggs	NP-385-H	H_2	Scan	-0.245	-0.263	-	60
	NP-385-H	H_2	Stepwise	-0.245	-0.263	0.054	29
Porte	NP-327-H	H_2	Scan	-	-0.263	-	-
Steigerwald	NP-385-H	H_2	Stepwise	-0.263	-0.262	0.05	8.37
Vaetn	NP-327-H	H_2	Stepwise	-	-0.260	0.089	140
Hatfield	NP-327-H	H_2	Scan	-0.262	-0.265	0.06	27
Economy & DiBari	NP-385-H	H_2	Stepwise	-0.253	-0.253	0.044	34
Wiene	NP-385-H	H_2	Stepwise	-0.264	-0.200	-	140
Saltzman	NP-327-H	H_2	Scan	-0.259	-0.272	0.063	77.5
Locke	NP-385-H	None	Stepwise	-0.240	-0.220	0.050	28
Walker	NP-385-H	N_2	Slow Scan	-	-0.22	0.050	24
	NP-385-H	N_2	Fast Scan	-	-0.22	Not Linear	18
Biefer	NP-327-H	N_2	Scan	-	-0.280	0.054	6.8
Prazak	NP-327-H	Air	Scan	-	-	-	14.5

Table IIIb

Comparison of Data Reported by Various Investigators for Potentiostatic Anodic Polarization Behavior of Nickel 270 in 1N H_2SO_4.

Investigator	Specimen Heat No.	Sat. Gas	Polarization Technique	Critical Potential (E_{cr}), Volt vs. S.C.E.	Passive Current Density (i_p), ma/cm^2	Early Transpassive Tafel Slope, volt/decade	Oxygen Evolution Tafel Slope, volt/decade
Myers	NP-385-H	H_2	Stepwise	+0.100 (+0.100 to +0.160)	0.019	0.14 to 0.15	0.09 to 0.10
	NP-327-H	H_2	Stepwise	+0.120 (+0.120 to +0.200)	0.015	0.13 to 0.14	0.08 to 0.09
Martin	NP-385-H	H_2	Scan (- to +)	+0.400	0.016	0.040	-
	NP-385-H	H_2	Scan (+ to -)	-0.040	0.0022	0.040	-
Riggs	NP-385-H	H_2	Scan	+0.250	0.30	-	-
	NP-385-H	H_2	Stepwise	+0.150	0.019	0.107	0.485
Porte	NP-327-H	H_2	Scan	-	-	-	-
Steigerwald	NP-385-H	H_2	Stepwise	-0.050	0.005	0.140	-
Vaeth	NP-327-H	H_2	Stepwise	+0.300	0.0198	0.182	-
Hatfield	NP-327-H	H_2	Scan	-0.025	0.05 to 0.18	0.17	0.37
Economy & Bibari	NP-385-H	H_2	Stepwise	+0.140 (+0.088 at i_{cr})	0.005	0.160	-
Wiene	NP-385-H	H_2	Stepwise	-0.050	0.003	-	-
Saltzman	NP-327-H	H_2	Scan	0.055	0.003	-	-
Locke	NP-385-H	None	Stepwise	-0.100	0.06	0.140	-
Walker	NP-385-H	N_2	Slow Scan	+0.11	0.02 to 0.2	0.185	-
	NP-385-H	N_2	Fast Scan	-0.05	about 0.1	Not Linear	-
Biefer	NP-327-H	N_2	Scan	+0.185	0.032	0.111	-
Prazak	NP-327-H	Air	Scan	-0.041	-	-	-

Appendix A

Data Sheets and Anodic Polarization Curves for the Fifteen Active Participants in T-3L Round Robin Test Program.

James R. Myers

Corrosion Research Laboratory

Air Force Institute of Technology

Wright-Patterson AFB, Ohio 45433

T-3L ROUND-ROBIN ANODIC POLARIZATION TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 22 ± 1 °C

D. Saturating Gas..... Purified Hydrogen

E. Specimen Preparation.... Ground through 4/0 emery paper, cleaned in boiling benzene, and rinsed in distilled water.

F. Specimen Activation Treatment..... Cathodically activated at -1.5 volts for 5 minutes.

G. Reference Electrode..... Saturated Calomel (S.C.E.)

H. Cathode Potential..... -0.269 volt vs. S.C.E.

I. Corrosion Potential..... -0.280 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)...

K. Anodic Potential Increment (if stepwise)..... 20 mv in active region, 40 mv in passive and transpassive

L. Time at Each Anodic Potential (if stepwise)... 3 minutes

M. Critical Current Density (i_{cr})..... 51 ma/cm^2

N. Critical Potential (E_{cr})..... +0.100 volt vs. S.C.E.

O. Passive Current Density (i_p)..... 0.019 ma/cm^2

P. Anodic Dissolution Tafel Slope... 0.050 to 0.070 volt/decade

Q. Transpassive Tafel Slope(s)..... (identify each)

a. Early transpassive: 0.140 to 0.150 volt/decade

b. Oxygen evolution: 0.090 to 0.100 volt/decade

R. Additional Comments..... Critical potential reported was potential associated with the critical current density. Passivation actually occurred over the potential range +0.100 to +0.160 volt vs. S.C.E.

Name James R. Myers

Address Corrosion Research Laboratory

Air Force Institute of Technology

Wright-Patterson AFB, Ohio 45433

T-3L ROUND-ROBIN ANODIC POLARIZATION TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-327-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 22 ± 1 °C

D. Saturating Gas..... Purified Hydrogen

E. Specimen Preparation.... Ground through 4/0 emery paper, cleaned in boiling benzene, and rinsed in distilled water.

F. Specimen Activation Treatment..... Cathodically activated at -1.5 volts for 5 minutes.

G. Reference Electrode..... Saturated Calomel (S.C.E.)

H. Cathode Potential..... -0.266 volt vs. S.C.E.

I. Corrosion Potential..... -0.271 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)...

K. Anodic Potential Increment (if stepwise)..... 10 mv in active region, 40 mv in passive and 20 mv in transpassive

L. Time at Each Anodic Potential (if stepwise)... 3 minutes

M. Critical Current Density (i_{cr})..... 67 ma/cm^2

N. Critical Potential (E_{cr})..... +0.120 volt vs. S.C.E.

O. Passive Current Density (i_p)..... 0.015 ma/cm^2

P. Anodic Dissolution Tafel Slope... 0.060 to 0.080 volt/decade

Q. Transpassive Tafel Slope(s)..... (identify each)

a. Larly transpassive: 0.130 to 0.140 volt/decade

b. Oxygen evolution: 0.080 to 0.090 volt/decade

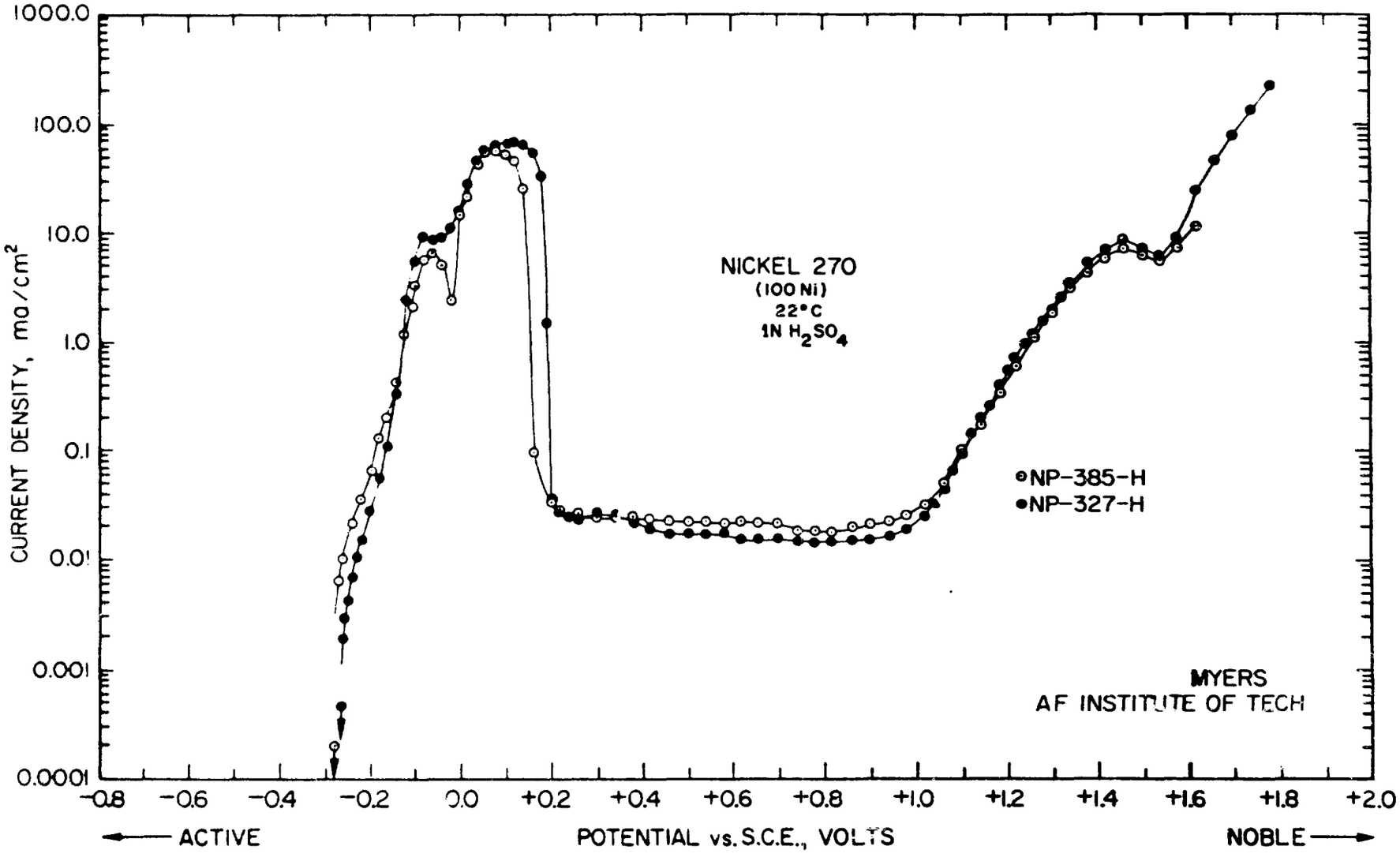
R. Additional Comments..... Critical potential reported was potential associated with the critical current density. Passivation actually occurred over the potential range +0.120 to +0.200 volt vs. S.C.E.

Name James R. Myers

Address Corrosion Research Laboratory

Air Force Institute of Technology

Wright-Patterson AFB, Ohio 45433



Potentiostatic Anodic Polarization Curves for Nickel 270 (Heats NP-385-H and NP-327-H) in H_2-Saturated, 1N H_2SO_4 at 22 $\pm$ 1 °C.

Richard L. Martin

Monsanto Company

800 North Lindberg Boulevard

St. Louis, Missouri 63166

CURVE NO. 1

T-3L ROUND-ROBIN ANODIC POLARIZATION
TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 25°C

D. Saturating Gas..... Ultrapure Hydrogen

E. Specimen Preparation.... Polished through 0000 emery paper, washed with soap and water, degreased with hot benzene, washed three times with distilled water, dried at 65°C for 15 minutes and cooled to room temperature (25°C) in desiccator.

F. Specimen Activation Treatment..... -0.300 volt cathodic for 15 minutes.

G. Reference Electrode..... Saturated calomel (S.C.E.)

H. Cathode Potential..... -0.267 volt vs. S.C.E.

I. Corrosion Potential..... -0.293 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)... 0.4 volt/hour

K. Anodic Potential Increment (if stepwise).....

L. Time at Each Anodic Potential (if stepwise)...

M. Critical Current Density (i_{cr})..... 190.0 ma/cm^2

N. Critical Potential (E_{cr})..... +0.400 volt

O. Passive Current Density (i_p)..... 0.016 ma/cm^2

P. Anodic Dissolution Tafel Slope... 0.050 volt/decade

Q. Transpassive Tafel Slope(s)..... 0.040 volt/decade
(identify each)

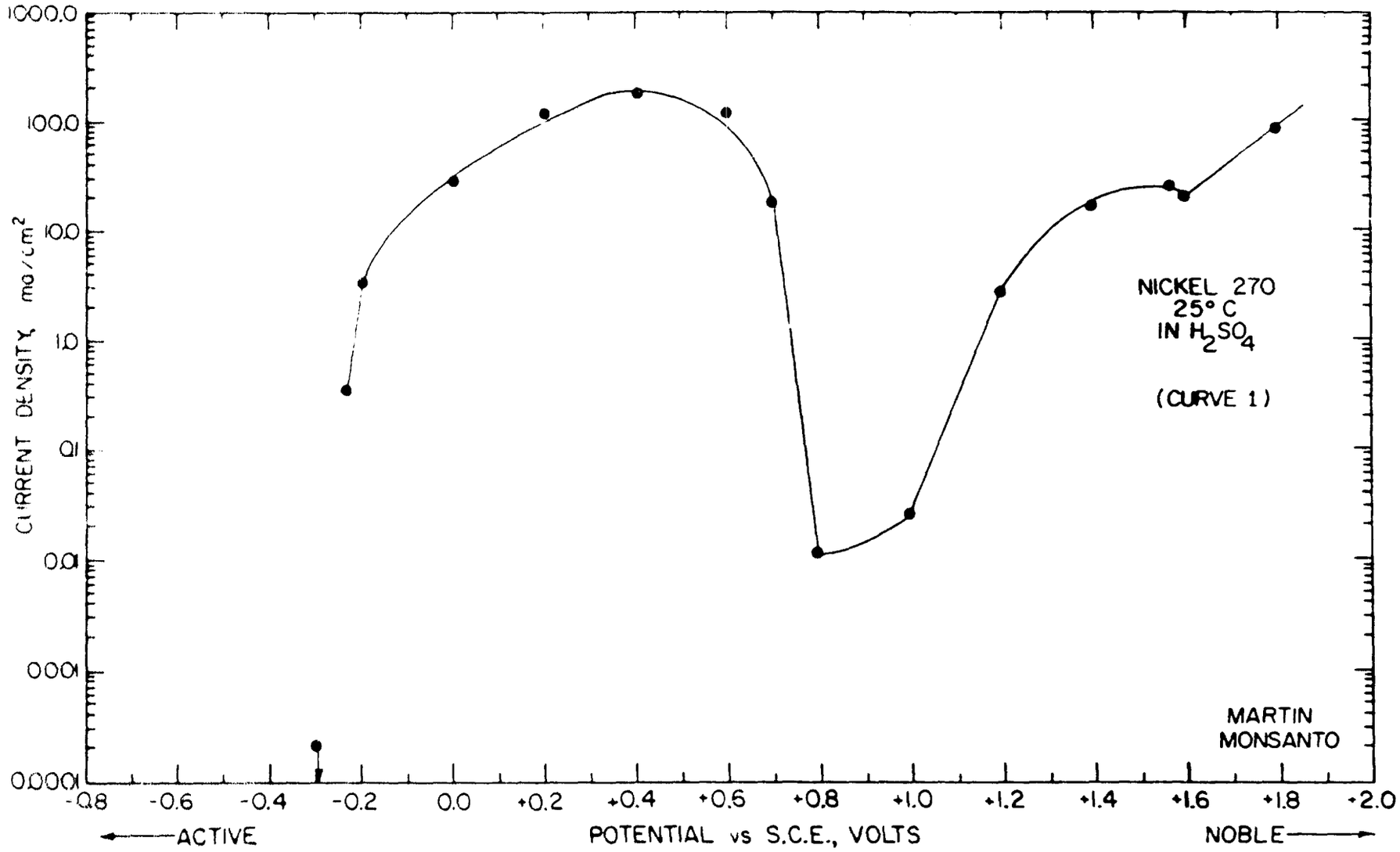
R. Additional Comments..... Curve No. 1 was obtained by traversing at 0.40 volt/hour from -0.30 volt to +1.40 volts.

Name Richard L. Martin

Address Monsanto Company

800 North Lindberg Boulevard

St. Louis, Missouri 63166



Potentiostatic Anodic Polarization Curve for Nickel 270 (Heat NP-385-H) in H_2-Saturated, 1N H_2SO_4 at 25 °C.

CURVE NO. 2

T-3L ROUND-ROBIN ANODIC POLARIZATION TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 25°C

D. Saturating Gas..... Ultrapure Hydrogen

E. Specimen Preparation.... Polished through 0000 emery paper, washed with soap and water, degreased with hot benzene, washed three times with distilled water, dried at 65°C for 15 minutes and cooled to room temperature (25°C) in desiccator.

F. Specimen Activation Treatment..... none

G. Reference Electrode..... Saturated calomel (S.C.E.)

H. Cathode Potential..... -0.267 volt vs. S.C.E.

I. Corrosion Potential..... -0.300 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)... 0.4 volt/hour

K. Anodic Potential Increment (if stepwise).....

L. Time at Each Anodic Potential (if stepwise)...

M. Critical Current Density (i_{cr})..... 38.12 ma/cm^2

N. Critical Potential (E_{cr})..... -0.040 volt

O. Passive Current Density (i_p) .... 0.0022 ma/cm^2

P. Anodic Dissolution Tafel Slope... 0.080 volt/decade

Q. Transpassive Tafel Slope(s)..... 0.040 volt/decade
(identify each)

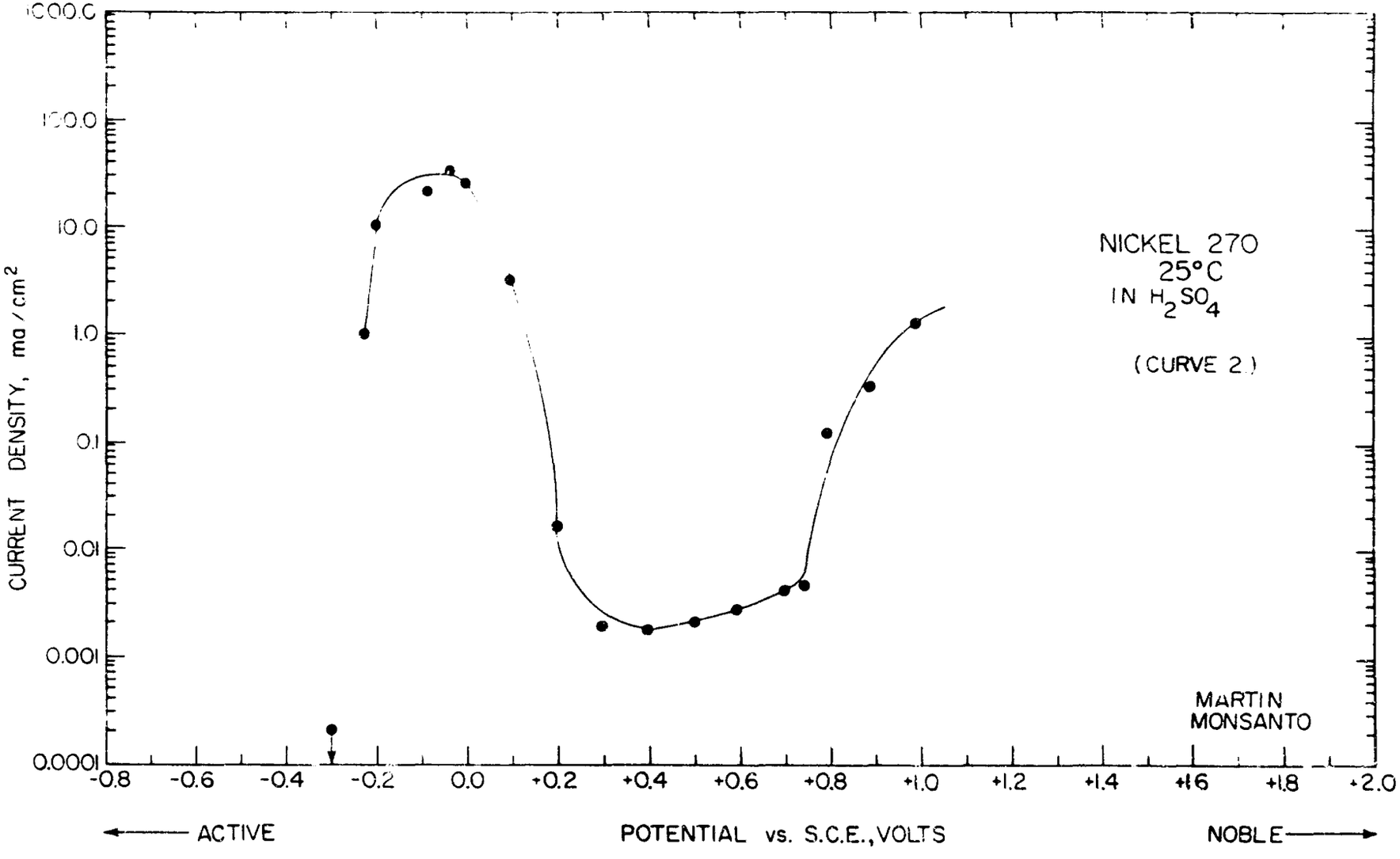
R. Additional Comments..... Curve No. 2 was obtained by traversing 0.40 volt/hour from 1.0 volt noble to -0.350 volt active.

Name Richard L. Martin

Address Monsanto Company

800 North Lindberg Boulevard

St. Louis, Missouri 63166



Potentiostatic Anodic Polarization Curve for Nickel 270 (Heat NP-385-H) in H_2-Saturated, 1N H_2SO_4 at 25 °C.

Olen L. Riggs

Continental Oil Company

P. O. Drawer 1267

Ponca City, Oklahoma 74601

T-3L ROUND-ROBIN ANODIC POLARIZATION TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 25°C

D. Saturating Gas..... H_2

E. Specimen Preparation.... Machine polished; the exposed portion of the specimen remained cylindrical (1/2" diameter, 1" length). A long (1 1/2") flat handle extended from center of top for electrical connection. The approximate surface area was calculated to be 10.7 cm^2.

F. Specimen Activation Treatment..... Cathodically activated at 50 ma/cm^2 for 30 minutes.

G. Reference Electrode..... Saturated calomel (S.C.E.)

H. Cathode Potential..... -0.245 ± .001 volt (active)

I. Corrosion Potential..... -0.263 ± .003 volt (active)

J. Anodic Potential Sweep Rate (if continuous)... 20 second scan

K. Anodic Potential Increment (if stepwise)..... 50 mv

L. Time at Each Anodic Potential (if stepwise).. 2 minutes

M. Critical Current Density (i_{cr}).....60.2 ma/cm^2 (scan) 29.0 ma/cm^2 (stepwise)

N. Critical Potential (E_{cr})..... +0.250 volt (scan) +0.150 volt (stepwise)

O. Passive Current Density (i_p)..... 0.30 ma/cm^2 (scan) 0.019 ma/cm^2 (stepwise)

P. Anodic Dissolution Tafel Slope... 0.054 volt/decade

Q. Transpassive Tafel Slope(s)..... (identify each)

1. Prior to secondary passivation:

0.107 volt/decade

2. After secondary passivation:

R. Additional Comments..... 0.485 volt/decade

(1) In my opinion, tafel slopes should traverse a minimum of 2 log decades preferably 3 or 4 to render the researcher meaningful information.

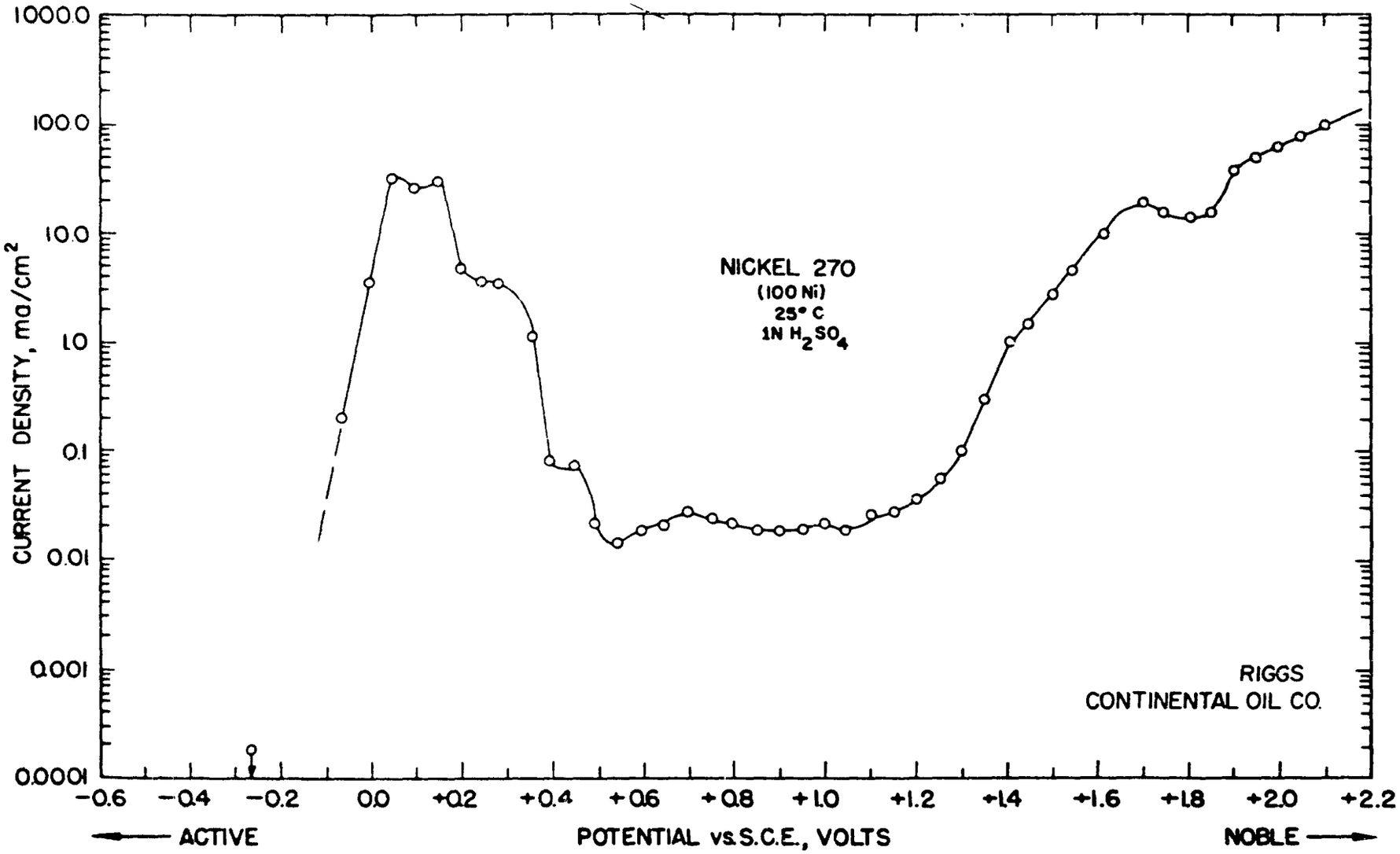
(2) Curve submitted was obtained stepwise.

Name Olen L. Riggs

Address Continental Oil Company

P. O. Drawer 1267

Ponca City, Oklahoma 74601



Potentiostatic Anodic Polarization Curve for Nickel 270
(Heat NP-385-H) in H_2-Saturated, 1N H_2SO_4 at 25°C.

Howard A. Porte

Chemistry Division

U. S. Naval Civil Engineering Laboratory

Port Hueneme, California 93041

T-3L ROUND-ROBIN ANODIC POLARIZATION TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-327-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 25°C

D. Saturating Gas..... H_2

E. Specimen Preparation.... Electrode was wet-polished (demineralized water as lubricant) with succeeding finer grades of silicon-carbide paper through No. 400, rinsed with demineralized water and inserted in cell.

F. Specimen Activation Treatment..... Left in solution overnight prior to polarization.

G. Reference Electrode..... Saturated calomel (S.C.E.)

H. Cathode Potential.....

I. Corrosion Potential..... -0.263 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)... 2 volts/hour

K. Anodic Potential Increment (if stepwise).....

L. Time at Each Anodic Potential (if stepwise)...

M. Critical Current Density (i_{cr}).....

N. Critical Potential (E_{cr}).....

O. Passive Current Density (i_p).....

P. Anodic Dissolution Tafel Slope...

Q. Transpassive Tafel Slope(s)..... _____
(identify each)

_____

_____

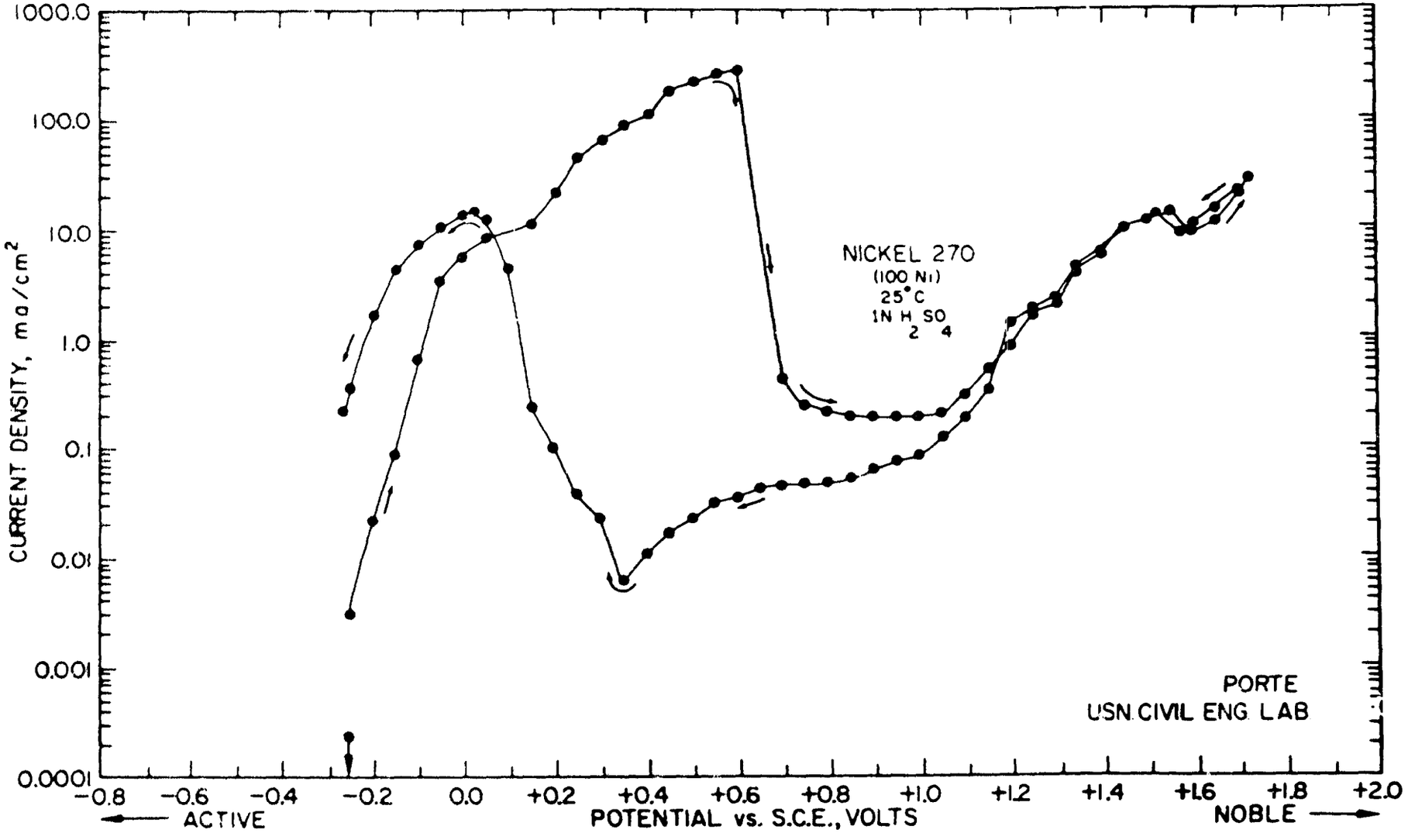
R. Additional Comments..... Polarization was conducted from corrosion potential in noble direction. After the transpassive region was reached, the potential sweep was reversed and polarization was conducted in the active direction.

Name Howard A. Porte

Address Chemistry Division

U. S. Naval Civil Engineering Laboratory

Port Hueneme, California 93041



Potentiostatic Anodic Polarization Curve for Nickel 270 (Heat NP-327-H) in H_2-Saturated, 1N H_2SO_4 at 25 °C.

R. F. Steigerwald

Engineering Materials Laboratory

E. I. du Pont de Nemours & Co.

Experimental Station

Wilmington, Delaware 19898

T-3L ROUND-ROBIN ANODIC POLARIZATION TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 26°C

D. Saturating Gas..... H_2

E. Specimen Preparation.... Ground on 400 grit emery; rinsed; etched in 10 parts formic acid - 10 parts hydrogen peroxide (30%) - 80 parts water at 80°C for 2 minutes; rinsed in distilled water.

F. Specimen Activation Treatment..... ~ 1 min at -0.6 volt vs. S.C.E.

G. Reference Electrode..... Saturated Calomel (S.C.E.)

H. Cathode Potential..... E = -0.2630 volt vs. S.C.E.

I. Corrosion Potential..... -0.2615 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)...

K. Anodic Potential Increment (if stepwise)..... Variable.

L. Time at Each Anodic Potential (if stepwise)... "steady-state" or 5 min.

M. Critical Current Density (i_{cr})..... 8.37 ma/cm^2

N. Critical Potential (E_{cr})..... -0.05 volt vs. S.C.E.

O. Passive Current Density (i_p)..... minimum i_p = 0.005 ma/cm^2

P. Anodic Dissolution Tafel Slope... 0.05 volt/decade

Q. Transpassive Tafel Slope(s)..... 0.14 volt/decade
(identify each)

R. Additional Comments.....

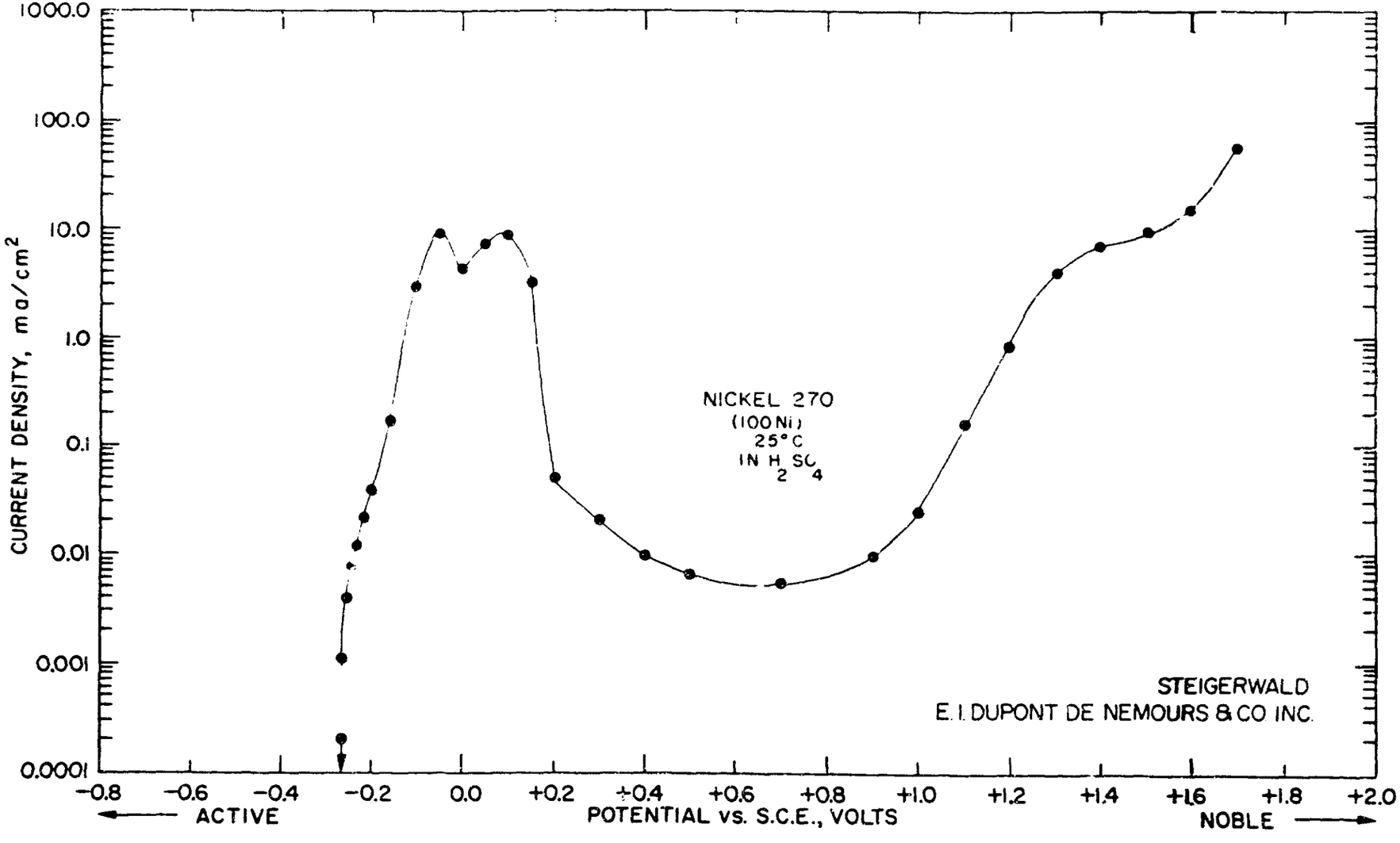
Name R. F. Steigerwald

Address Engineering Materials Laboratory

E. I. du Pont de Nemours & Co.

Experimental Station

Wilmington, Delaware 19898



Potentiostatic Anodic Polarization Curve for Nickel 270
(Heat NP-385-H) in H_2-Saturated, 1N H_2SO_4 at 26 °C.

Howard Vaeth

Republic Steel Corporation

Research Center

6801 Brecksville Road

Independence, Ohio 44131

T-3L ROUND-ROBIN ANODIC POLARIZATION TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-327-H)

B. Electrolyte.....

C. Temperature, °C..... 24 ± 1 °C

D. Saturating Gas..... Hydrogen

E. Specimen Preparation.... Cross section of sample mounted in plastic (Quickmount) and polished metallographically, finishing with 0.05 micron alumina.

F. Specimen Activation Treatment..... One hour age in electrolyte followed by one minute at -0.500 volt followed by a one minute period after which the polarization run was started.

G. Reference Electrode..... Saturated Calomel (S.C.E.)

H. Cathode Potential.....

I. Corrosion Potential..... -0.260 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)...

K. Anodic Potential Increment (if stepwise)..... 20 mv

L. Time at Each Anodic Potential (if stepwise)... 2 minutes

M. Critical Current Density (i_{cr})..... 140 ma/cm^2

N. Critical Potential (E_{cr})..... 0.3 volt vs. S.C.E. See reverse side

O. Passive Current Density (i_p)..... 19.8 μ a/sq cm

P. Anodic Dissolution Tafel Slope... 0.089 volt/decade

Q. Transpassive Tafel Slope(s)..... 0.182 volt/decade
(identify each)
This is before the transpassive inflection.

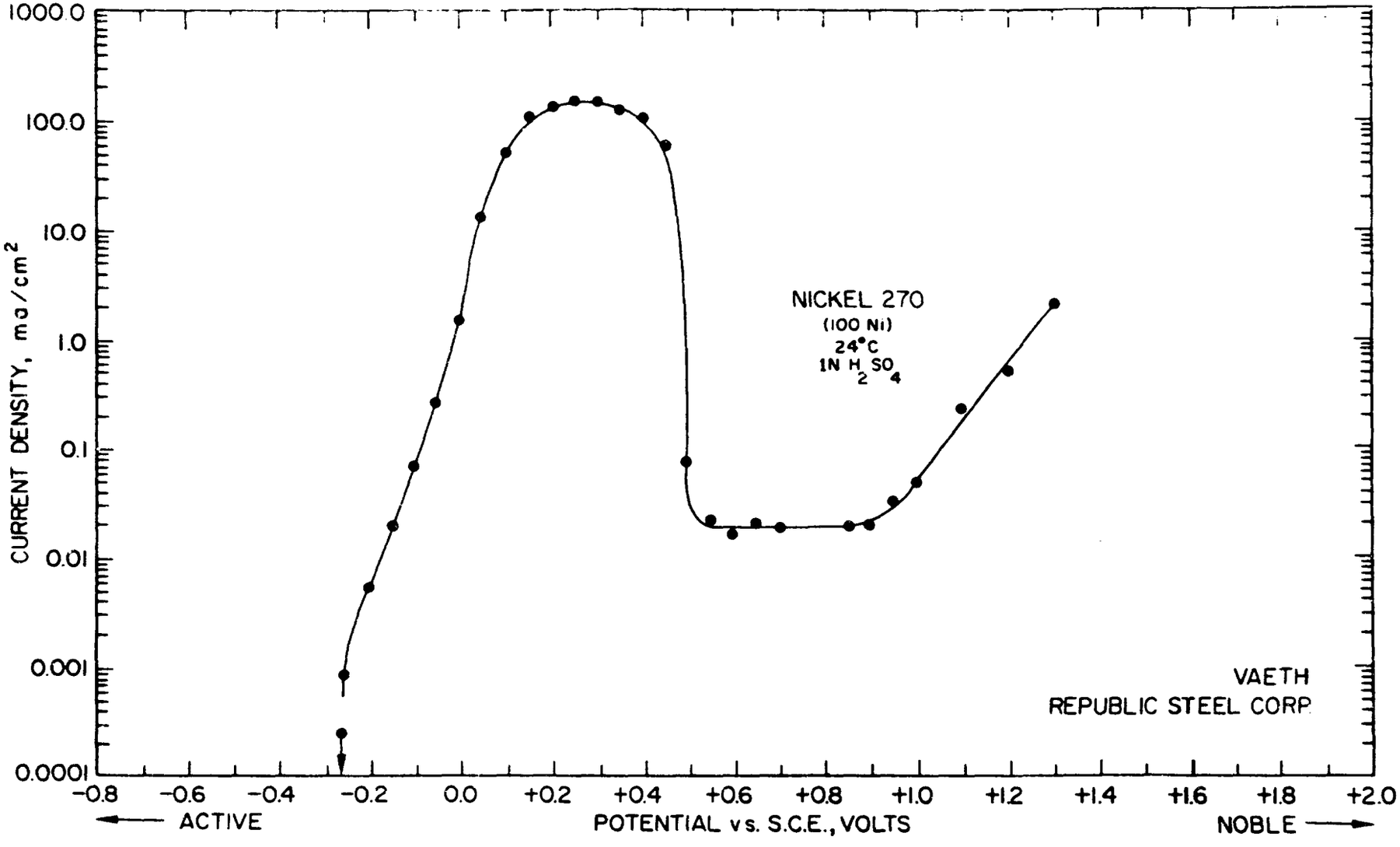
R. Additional Comments.....

1. Critical Potential. No distinct "nose" was observed. Rather a range of potentials over which the current remained at a constant maximum value was observed. The approximate middle of this potential range is at 0.3 volt and is the value reported on the reverse side. The current density through this range is taken as the critical current density.

2. General. Four runs were made using four cross sections cut from the original sample.

Name Howard Vaeth

Address Republic Steel Corporation
Research Center
6801 Brecksville Road
Independence, Ohio 44131



Potentiostatic Anodic Polarization Curve for Nickel 270
(Heat NP-327-H) in H_2-Saturated, 1N H_2SO_4 at 24 $\pm$ 1 °C.

John D. Hatfield

Fundamental Research Branch

TVA National Fertilizer Development Center

Muscle Shoals, Alabama 35660

T-3L ROUND-ROBIN ANODIC POLARIZATION TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-327-H)

B. Electrolyte..... 1.0N H_2SO_4

C. Temperature, °C..... 25.0 °C

D. Saturating Gas..... Hydrogen

E. Specimen Preparation.... Ground with Nos. 2, 1, 0, 2/0, 3/0 and 4/0 emery paper in kerosene. Washed at 25 °C in acetone. Dried 20 minutes at 60 °C and desiccated overnight at room temperature.

F. Specimen Activation Treatment.....Cathodized in 1N H_2SO_4 immediately prior to measurements at approximately 1 ampere for 5 minutes.

G. Reference Electrode..... Saturated calomel (S.C.E.)

H. Cathode Potential..... Initially -0.262 volt vs. S.C.E.

I. Corrosion Potential..... -0.265 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)... 2.50 mv/min

K. Anodic Potential Increment (if stepwise).....

L. Time at Each Anodic Potential (if stepwise)...

M. Critical Current Density (i_{cr})..... 27 ma/cm^2

N. Critical Potential (E_{cr})..... -0.025 volt vs. S.C.E.

O. Passive Current Density (i_p)..... 0.05 to 0.18 ma/cm^2

P. Anodic Dissolution Tafel Slope... 0.06 volt/decade

Q. Transpassive Tafel Slope(s)..... (identify each) No oxygen evolution: 0.17 volt/decade

With oxygen evolution: 0.37 volt/decade

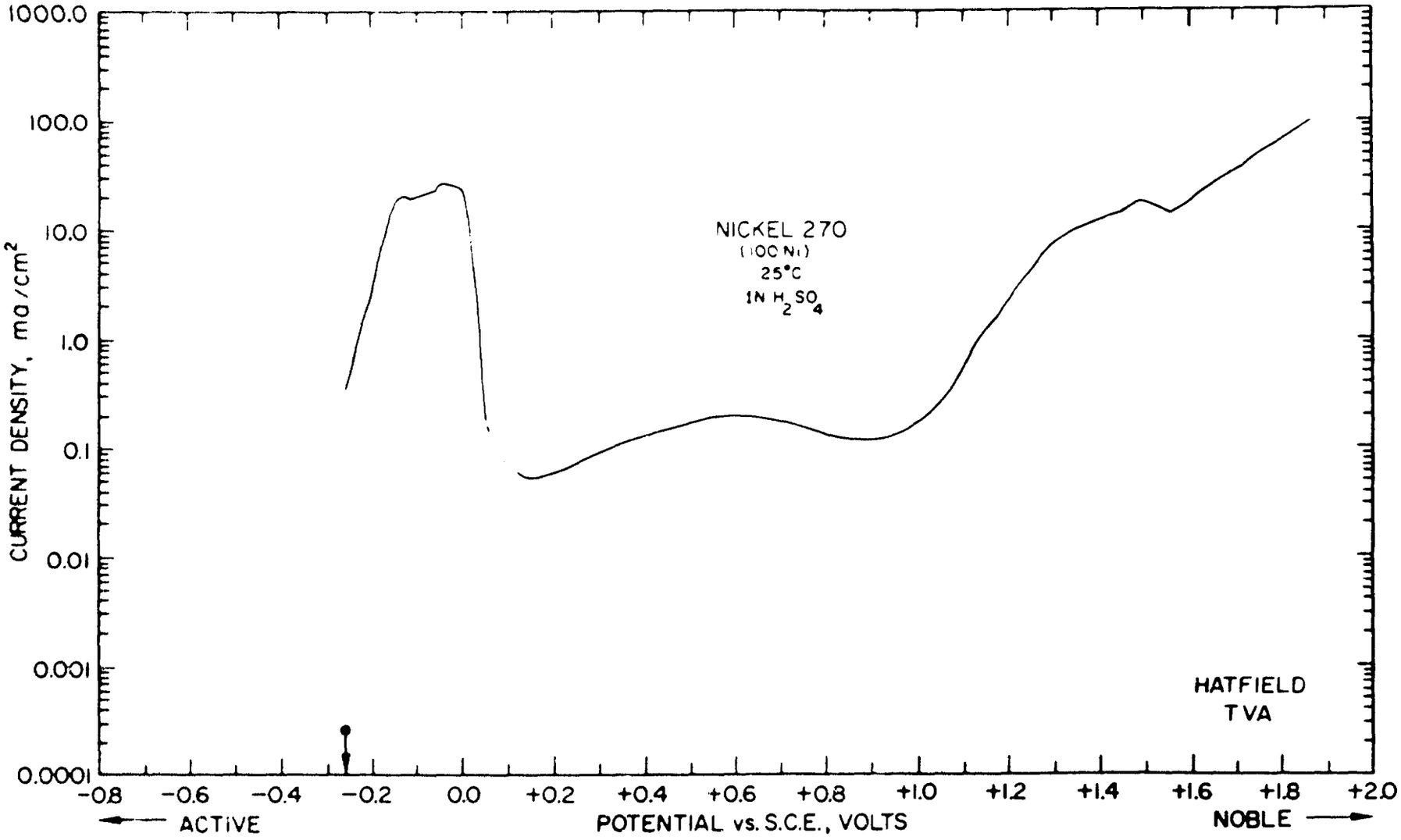
R. Additional Comments..... The attached curve is a composite of two runs. Although anodic dissolution and transpassive dissolution slopes, as well as passivation currents of each run, were essentially identical, the first specimen (not subjected to an activation treatment) failed to passivate until a current density of 150 ma/cm^2 at a potential of +0.32 volt vs. SCE had been attained.

Name John D. Hatfield

Address Fundamental Research Branch

TVA National Fertilizer Development Center

Muscle Shoals, Alabama 35660



Potentiostatic Anodic Polarization Curves for Nickel 270 (Heat NP-327-H) in H_2-Saturated, 1N H_2SO_4 at 25 °C.

George Economy & C. A. Bibari

Paul D. Merica Research Laboratory

The International Nickel Company, Inc.

Sterling Forest

Suffern, New York 10901

T-3L ROUND-ROBIN ANODIC POLARIZATION
TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... 1.0000N H_2SO_4

C. Temperature, °C..... 25 + 0.5 °C

D. Saturating Gas..... Hydrogen (Deoxo Purified)

E. Specimen Preparation.... Exposed surface given mirror polish.

F. Specimen Activation Treatment..... Degreased in acetone, rinsed in distilled water, immersed in 1 to 1 nitric-acetic acid solution, rinsed in distilled water, and held in [illegible] until placed in cell.

G. Reference Electrode..... [illegible]

H. Cathode Potential..... [illegible]

I. Corrosion Potential..... [illegible] volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)... _____

K. Anodic Potential Increment (if stepwise)..... Irregular

L. Time at Each Anodic Potential (if stepwise)... 5 minutes to 16 hours

M. Critical Current Density (i_{cr})..... [illegible] ma/cm²

N. Critical Potential (E_{cr})..... [illegible] volt vs. S.C.E.

O. Passive Current Density (i_p)..... [illegible] μa/cm²

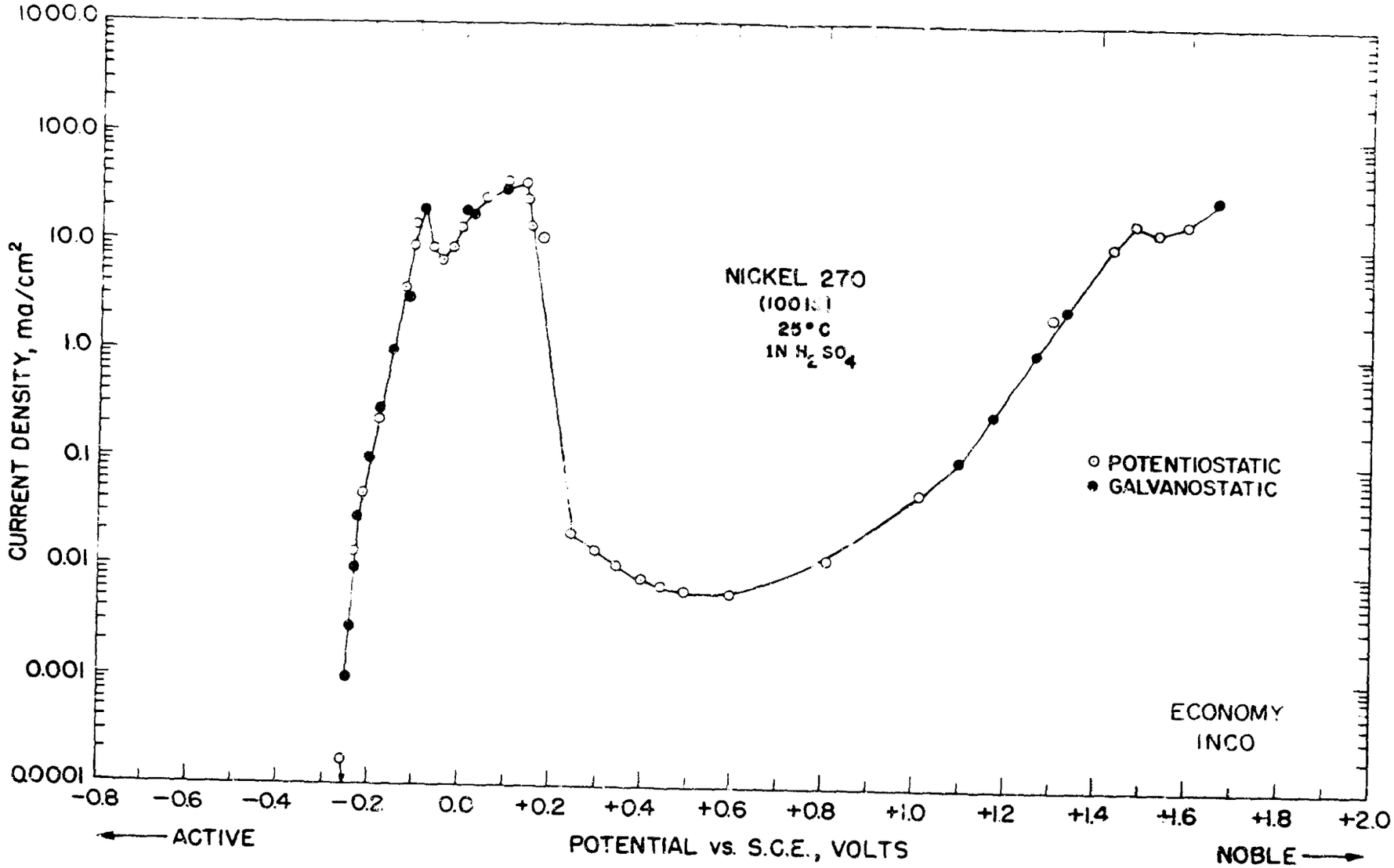
P. Anodic Dissolution Tafel Slope... [illegible] volt/decade

Q. Transpassive Tafel Slope(s)..... 0.160 volt/decade
(identify each)

R. Additional Comments..... E_{cr} would be +0.088 volt vs. S.C.E.
if taken at i_{cr}.

Name [illegible] C. F. Bonilla

Address Paul D. Merica Research Laboratory
The International Nickel Company, Inc.
Sterling Forest
Suffern, New York 10901



Potentiostatic and Galvanostatic Anodic Polarization Curves for Nickel 270 (Heat NP-385-H) in H_2-Saturated, 1N H_2SO_4 at 25 ± 0.5 °C.

Edward L. Wiehe

J & L Graham Research Laboratory

900 Agnew Road

Pittsburgh, Pennsylvania 15227

T-3L ROUND-ROBIN ANODIC POLARIZATION TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... $1\overline{N}$ H_2SO_4

C. Temperature, °C..... Start 23°C Finish 24°C

D. Saturating Gas..... H_2

E. Specimen Preparation....Finished with 120 grit paper and then degreased in an ultrasonic cleaner.

F. Specimen Activation Treatment..... Electrode immersed overnight in H_2 - saturated cell prior to polarization studies.

G. Reference Electrode..... Saturated Calomel (S.C.E.)

H. Cathode Potential..... -.2646 volt vs. S.C.E. (start); -.2640 volt vs. S.C.E. (finish)

I. Corrosion Potential..... -.2000 volt vs. S.C.E. (time dependent)

J. Anodic Potential Sweep Rate (if continuous)...

K. Anodic Potential Increment (if stepwise)..... 25 mv to i_{cr} then 50 mv

L. Time at Each Anodic Potential (if stepwise)... 5 minutes

M. Critical Current Density (i_{cr})..... 140,000 μ amp/cm^2

N. Critical Potential (E_{cr})..... -.0500 volt

O. Passive Current Density (i_p)..... 3 μ amp/cm^2

P. Anodic Dissolution Tafel Slope... not determined

Q. Transpassive Tafel Slope(s)..... Not determined.
(identify each)

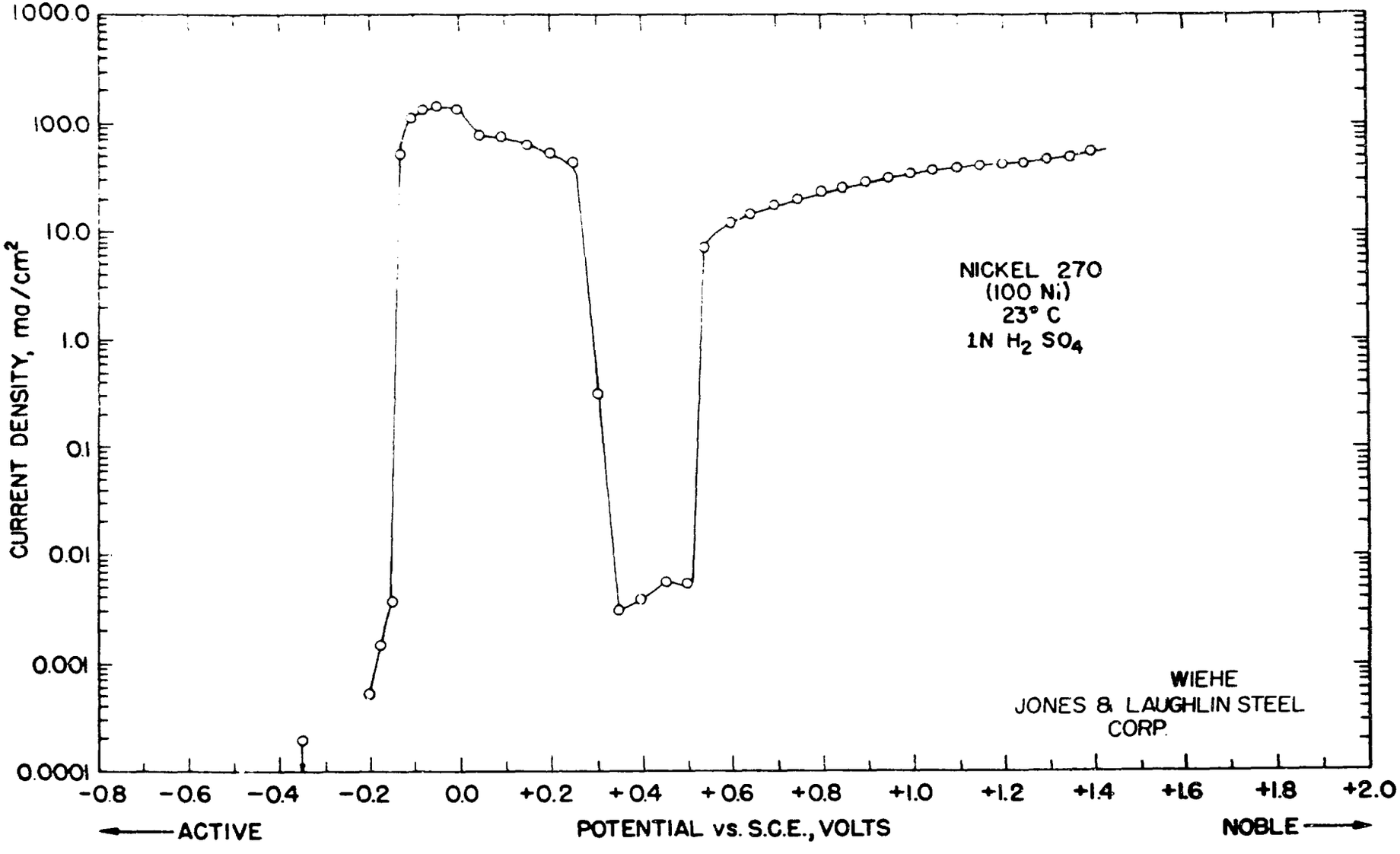
R. Additional Comments.....

Name Edward L. Wiehe

Address J & L Graham Research Laboratory

900 Agnew Road

Pittsburgh, Pennsylvania 15227



Potentiostatic Anodic Polarization Curve for Nickel 270
(Heat NP-385-H) in H_2-Saturated, 1N H_2SO_4 at 23-24 °C.

G. A. Saltzman

Crucible Steel Co. of America

Central Research Laboratory

234 Atwood Street

Pittsburgh, Pennsylvania 15213

T-3L ROUND-ROBIN ANODIC POLARIZATION TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-327-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 25 ± 1 °C

D. Saturating Gas..... H_2

E. Specimen Preparation.... Surface abraded with 500 grit silicon carbide paper, scrubbed with an alkaline cleaner, degreased in hot chloroform, rinsed with distilled water.

F. Specimen Activation Treatment..... Pre-exposure to test solution for 1 hour prior to beginning potentiostatic polarization.

G. Reference Electrode..... Saturated Calomel

H. Cathode Potential..... -0.259 volt vs. S.C.E.

I. Corrosion Potential..... -0.272 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)... 0.64 volt/hour

K. Anodic Potential Increment (if stepwise).....

L. Time at Each Anodic Potential (if stepwise)...

M. Critical Current Density (i_{cr})..... 7.75×10^4 μ a/cm^2

N. Critical Potential (E_{cr})..... 0.055 volt vs. S.C.E.

O. Passive Current Density (i_p)..... 3 μ a/cm^2 (minimum)

P. Anodic Dissolution Tafel Slope... 0.063 volt/decade

Q. Transpassive Tafel Slope(s)..... Not determined
(identify each)

R. Additional Comments.....

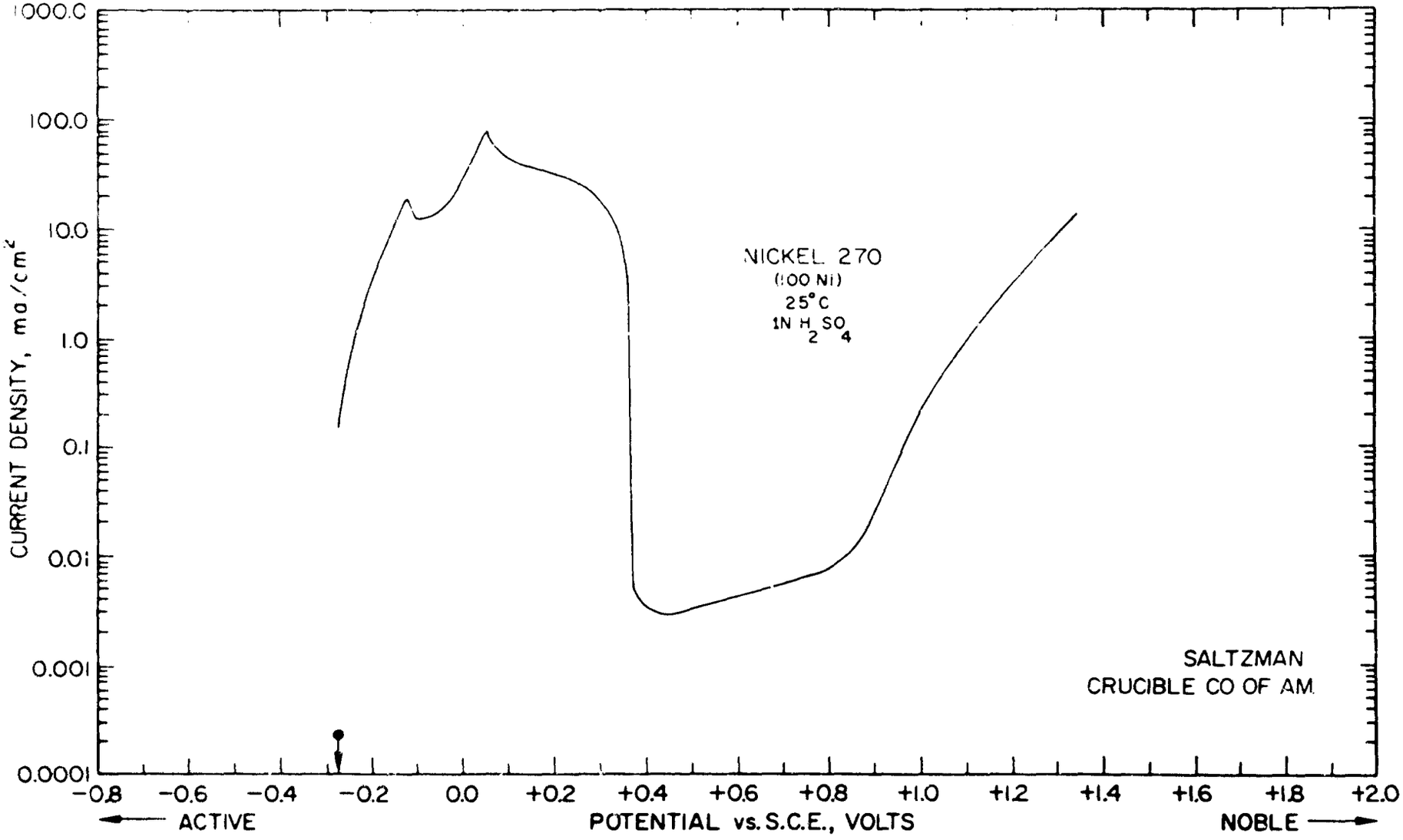
Name G. A. Saltzman

Address Crucible Steel Co. of America

Central Research Laboratory

234 Atwood Street

Pittsburgh, Pennsylvania 15213



Potentiostatic Anodic Polarization Curve for Nickel 270
(Heat NP-327-H) in H_2-Saturated, 1N H_2SO_4 at 25 ± 1 °C.

C. E. Locke

Anotrol Division

Continental Oil Company

P. O. Drawer 1267

Ponca City, Oklahoma 74601

T-3L ROUND-ROBIN ANODIC POLARIZATION
TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 25 °C

D. Saturating Gas..... None

E. Specimen Preparation.... Abraded on a disc sander (medium grit) followed by silicon carbide sanding disc. Washed with H_2O, acetone, and dried.

F. Specimen Activation Treatment..... Catnodically activated at 15 ma/in^2 for three minutes in test solution.

G. Reference Electrode..... Saturated Calomel Electrode (S.C.E.)

H. Cathode Potential..... -240 mv (active) vs. S.C.E.

I. Corrosion Potential..... -220 mv (active) vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)...

K. Anodic Potential Increment (if stepwise)..... 100 mv

L. Time at Each Anodic Potential (if stepwise)... 3 minutes

M. Critical Current Density (i_{cr})..... 28 ma/in^2

N. Critical Potential (E_{cr})..... -100 mv (active)

O. Passive Current Density (i_p)..... 0.06 ma/in^2

P. Anodic Dissolution Tafel Slope... 50 mv/decade

Q. Transpassive Tafel Slope(s)..... 140 mv/decade
(identify each)

R. Additional Comments.....

Name C. E. Locke

Address Anotrol Division

Continental Oil Company

P. O. Drawer 1267

Ponca City, Oklahoma 74601

Monte S. Walker

General Motors Technical Center

12 Mile and Mound Roads

Warren, Michigan 48090

T-3L ROUND-ROBIN ANODIC POLARIZATION
TEST PROGRAM DATA SHEET

SLOW SWEEP RATE

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 25°C

D. Saturating Gas..... Nitrogen

E. Specimen Preparation.... The specimen was polished with emery paper, finishing with a 0000 grade. It was then stored in a desiccator. Just prior to use, it was repolished with 0000 emery paper and rinsed in alcohol and distilled water.

F. Specimen Activation Treatment..... Cathodically activated at -1.85 volt for 5 minutes.

G. Reference Electrode..... Saturated calomel (S.C.E.)

H. Cathode Potential.....

I. Corrosion Potential..... -0.22 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)... 1/3 volt hour

K. Anodic Potential Increment (if stepwise).....

L. Time at Each Anodic Potential (if stepwise)...

M. Critical Current Density (i_{cr})..... 24 ma/cm^2

N. Critical Potential (E_{cr})..... +0.11 volt vs. S.C.E.

O. Passive Current Density (i_p)..... 0.02 to 0.2 ma/cm^2

P. Anodic Dissolution Tafel Slope... 0.050 volt/decade

Q. Transpassive Tafel Slope(s)..... 0.185 volt/decade
(identify each)

R. Additional Comments.....

(1) The electrolyte was mechanically stirred at the rate of 250 rpm.

(2) Initially, the test specimen was prepared using the full 1/2-inch bar of Inconel 270. This specimen would not passivate. Preferential attack of the outer edge of the specimen occurred during a controlled potential sweep. By machining the specimen down to 0.50 cm^2, the edge suffering preferential attack was eliminated.

Name Monte S. Walker

Address General Motors Technical Center
12 Mile and Mound Roads
Warren, Michigan 48090

T-3L ROUND-ROBIN ANODIC POLARIZATION
TEST PROGRAM DATA SHEET

FAST SWEEP RATE

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 25°C

D. Saturating Gas..... Nitrogen

E. Specimen Preparation.... The specimen was polished with emery paper, finishing with 0000 grade. It was then stored in a desiccator. Just prior to use, it was repolished with 0000 emery paper and rinsed in alcohol and distilled water.

F. Specimen Activation Treatment..... Cathodically activated at -1.85 volt for 5 minutes

G. Reference Electrode..... Saturated calomel (S.C.E.)

H. Cathode Potential.....

I. Corrosion Potential..... -0.22 volt vs. S.C.E.

J. Anodic Potential Sweep Rate (if continuous)... 30 volts/hour

K. Anodic Potential Increment (if stepwise).....

L. Time at Each Anodic Potential (if stepwise)...

M. Critical Current Density (i_{cr})..... 18 ma/cm^2

N. Critical Potential (E_{cr})..... -0.05 volt vs. S.C.E.

O. Passive Current Density (i_p)..... ~ 1 ma/cm^2

P. Anodic Dissolution Tafel Slope... Not linear

Q. Transpassive Tafel Slope(s)..... Not linear
(identify each)

R. Additional Comments.....

(1) The electrolyte was mechanically stirred at the rate of 250 rpm.

(2) At the fast scan rate (30 volt/hour), the second current maximum does not have time to develop.

Name Monte S. Walker

Address General Motors Technical Center
12 Mile and Mound Roads
Warren, Michigan 48090

G. J. Biefer

Corrosion Section

Physical Metallurgy Division

Mines Branch of Canada

568 Booth Street

Ottawa, Ont, Canada

T-3L ROUND-ROBIN ANODIC POLARIZATION
TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-327-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 23.5 °C

D. Saturating Gas..... Purified Nitrogen

E. Specimen Preparation.... Surface-ground by hand on 120 grit silicon carbide paper under water cooling, rinsed in water, cleaned in ultrasonically agitated carbon tetrachloride, then alcohol, then dried in a blast of hot air.

F. Specimen Activation Treatment..... Specimen immersed in test solution (1.6 litres) for 1 hour prior to measurements.

G. Reference Electrode..... Saturated Calomel (S.C.E.)

H. Cathode Potential.....

I. Corrosion Potential..... -280 mv vs S.C.E.

J. Anodic Potential Sweep Rate (if continuous)... 7 volts/hour

K. Anodic Potential Increment (if stepwise).....

L. Time at Each Anodic Potential (if stepwise)...

M. Critical Current Density (i_{cr})..... 6.8 ma/cm^2

N. Critical Potential (E_{cr})..... +185 mv vs S.C.E.

O. Passive Current Density (i_p)..... 32 μ a/cm^2 (minimum)

P. Anodic Dissolution Tafel Slope... .054 volt/decade (from ~ 0.2 ma/cm^2 to ~ 2 ma/cm^2)

Q. Transpassive Tafel Slope(s)..... 111 mv/decade (from ~ 0.2 ma/cm^2 to ~ 2 ma/cm^2)
(identify each)

R. Additional Comments..... H_2- purifier at present under repair.

N_2 has been used in the past, at this laboratory, for this kind of run.

Name G. J. Biefer

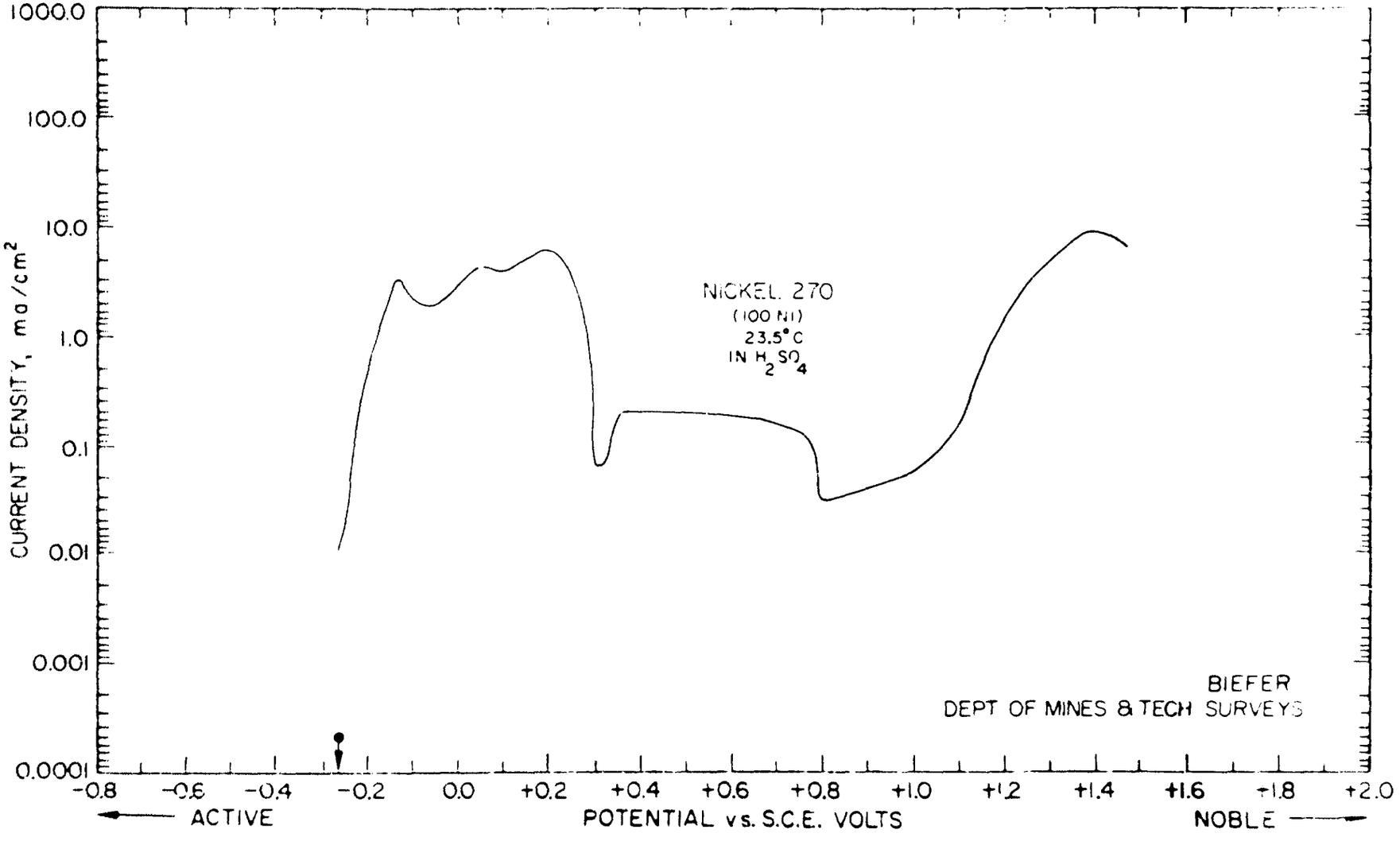
Address Corrosion Section

Physical Metallurgy Division

Mines Branch of Canada

568 Booth Street

Ottawa, Ont, Canada



Potentiostatic Anodic Polarization Curve for Nickel 270 (Heat NP-327-H) in N_2-Saturated, 1N H_2SO_4 at 23.5 °C.

Ing. M. Pražák CSc.

State Institute for Material

Protection Research,

Prague 7

Czechoslovakia

Ing M. Pražák CSc.

State Institute for Material

Protection Research,

Prague 7

Czechoslovakia

T-3L ROUND-ROBIN ANODIC POLARIZATION
TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-327-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 20°C

D. Saturating Gas..... Air

E. Specimen Preparation.... Mechanically polished, followed by registration of the curve 2 times from -0.6 to +1.6 volts vs. S.C.E. (i.e., electrochemically etched) before final registration; final registration = Curve No. 3.

F. Specimen Activation Treatment..... at -0.6 volt (see above)

G. Reference Electrode..... Saturated calomel (S.C.E.) with satd. NH_4NO_3 junction

H. Cathode Potential.....

I. Corrosion Potential.....

J. Anodic Potential Sweep Rate (if continuous)... +0.010 volt/sec.

K. Anodic Potential Increment (if stepwise).....

L. Time at Each Anodic Potential (if stepwise)...

M. Critical Current Density (i_{cr})..... 14.5 ma/cm^2

N. Critical Potential (E_{cr})..... -0.041 volt vs. S.C.E.

O. Passive Current Density (i_p)..... cannot be determined

P. Anodic Dissolution Tafel Slope...

Q. Transpassive Tafel Slope(s)..... _____
(identify each)

_____

_____

R. Additional Comments..... _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

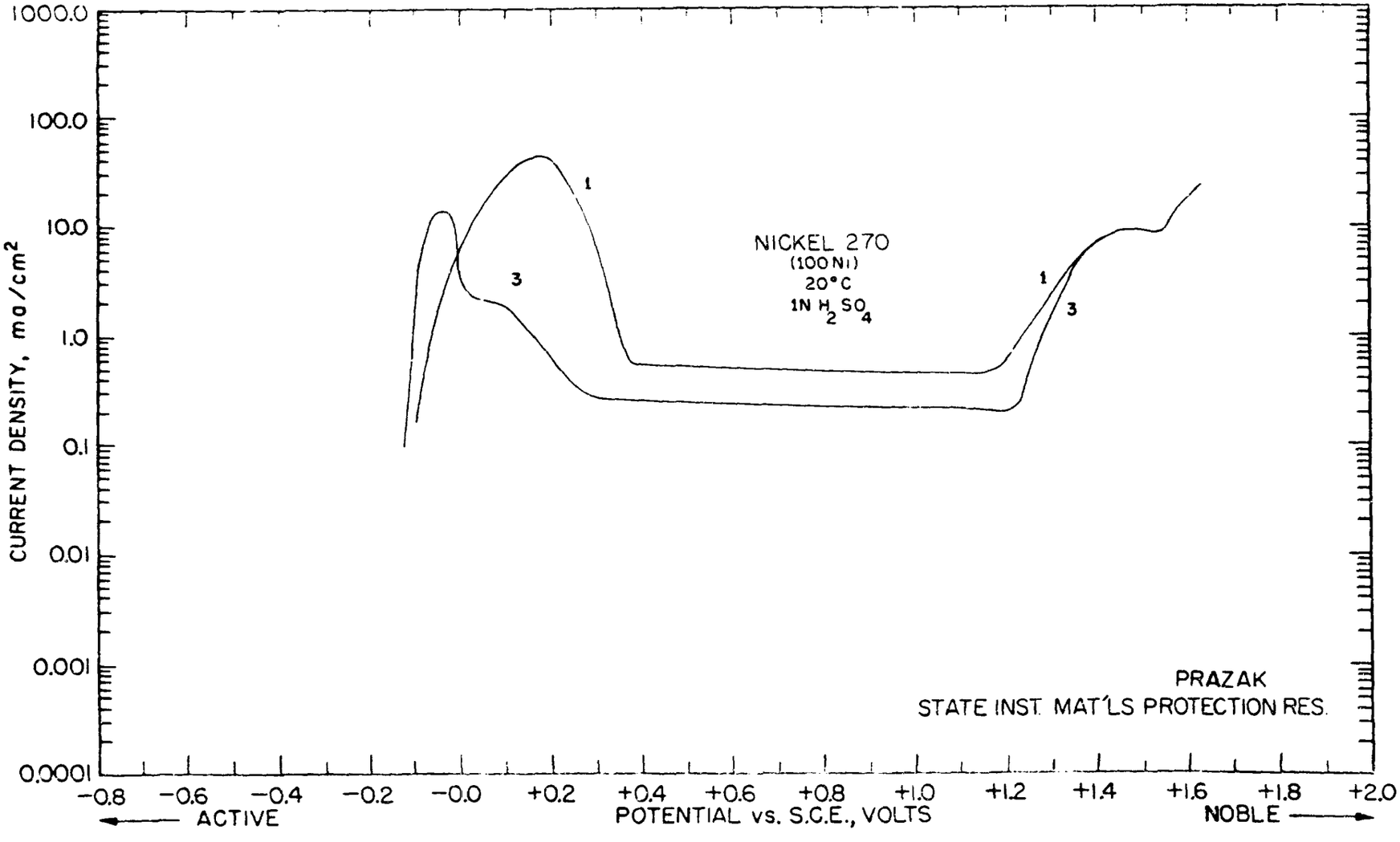
Name Ing. M. Pražák CSc.

Address State Institute for Material

Protection Research,

Prague 7

Czechoslovakia



Potentiostatic Anodic Polarization Curves for Nickel 270
(Heat NP-327-H) Air-Saturated, 1N H_2SO_4 at 20 °C.

James W. Johnson

Department of Chemical Engineering

University of Missouri at Rolla

Rolla, Missouri 65401

T-3L ROUND-ROBIN ANODIC POLARIZATION
TEST PROGRAM DATA SHEET

A. Specimen..... Nickel 270 (NP-385-H)

B. Electrolyte..... 1N H_2SO_4

C. Temperature, °C..... 25°C

D. Saturating Gas..... H_2

E. Specimen Preparation.... Mounted in Teflon holder, smoothed with belt sander (wet), final polished with No. 600 grit wet hand grinder.

F. Specimen Activation Treatment..... Etched 30 seconds in 1N H_2SO_4

G. Reference Electrode..... Mercurous sulfate (1N H_2SO_4)

H. Cathode Potential..... -0.011 volt (rest pot. of Ni)

I. Corrosion Potential..... <0.087 volt

J. Anodic Potential Sweep Rate (if continuous)...

K. Anodic Potential Increment (if stepwise)..... galvanostatic measurement

L. Time at Each Anodic Potential (if stepwise)... 1 hour

M. Critical Current Density (i_{cr})..... 4 to 5 ma/cm^2

N. Critical Potential (E_{cr})..... 0.2 volt (NHS)

O. Passive Current Density (i_p)..... Not determined

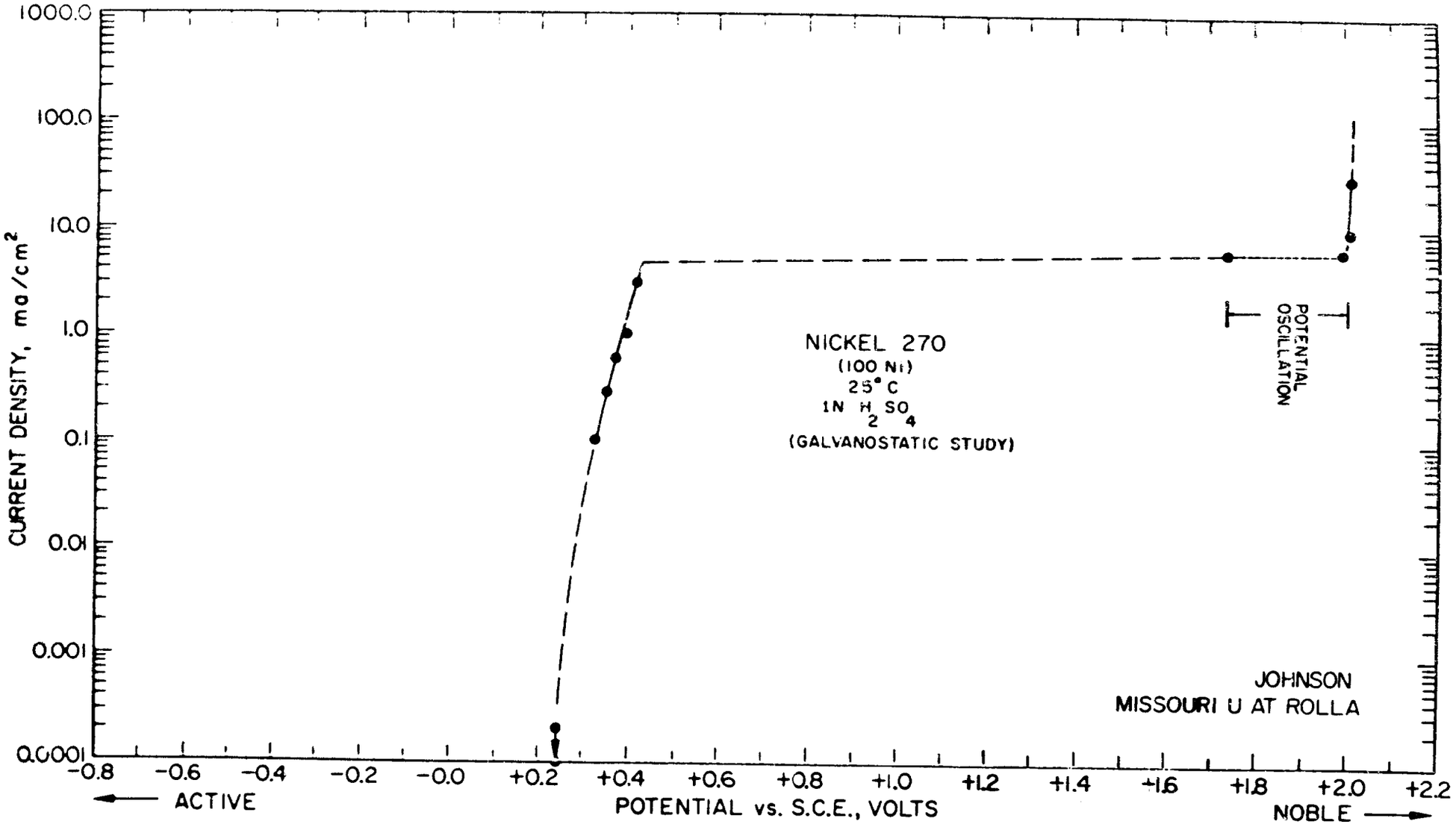
P. Anodic Dissolution Tafel Slope... 0.062 volt/decade

Q. Transpassive Tafel Slope(s)..... 1st: about 0.120 volt/decade
(identify each)

R. Additional Comments..... Experiments were made galvanostatically, so that "active-to-passive" and "passive" region could not be determined.

Name James W. Johnson

Address Department of Chemical Engineering
University of Missouri at Rolla
Rolla, Missouri 65401



Galvanostatic Anodic Polarization Curve for Nickel 270 (heat NP-385-H) in H_2-Saturated, 1N H_2SO_4 at 25 °C.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Air Force Institute of Technology Wright-Patterson AFB, Ohio 45433	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

ANODIC POLARIZATION BEHAVIOR OF NICKEL 270 IN H_2-SATURATED, IN H_2SO_4*

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Research Report

5. AUTHOR(S) (First name, middle initial, last name)

James R. Myers

6. REPORT DATE April 1967	7a. TOTAL NO. OF PAGES 74	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) AFIT TR 67-4 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) X	

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Corrosion Research Laboratory Air Force Institute of Technology Wright-Patterson AFB, Ohio 45433

13. ABSTRACT

*Results of a round-robin test program conducted by National Association of Corrosion Engineers Technical Committee T-3L for Anodic Protection.

DD FORM 1 NOV 65 1473

Unclassified

Security Classification